Conservative and non-conservative variability in the inherent optical properties of dissolved and particulate components in seawater

Collin S. Roesler
Department of Marine Sciences, The University of Connecticut
1084 Shennecossett Rd., Groton, CT 06340-6097
phone: (860) 405-9166 fax: (860) 405-9153 email: roesler@uconnvm.uconn.edu
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LONG TERM GOAL

The long term goals of this project are to develop methods for separating the observed variability in the inherent optical properties (iops) into conservative and non-conservative components, with the goal to use optical measurements to simultaneously provide information about the physical and bio/chemical processes in the water column, respectively.

SCIENTIFIC OBJECTIVES

Optical measurements originated with the single wavelength beam attenuation coefficient, $c(l_o)$, which was used as an indicator of suspended material in seawater. The capability exists now to measure the spectral *c* and separate it into its absorbing and scattering components, *a* and *b* (Fig. 1a). Towards the goal of identifying conservative and non-conservative variations in the iops as indicators of physical and bio/chemical processes in the water column, it is necessary to deconvolve further the bulk *a* and *b* coefficients to explicitly identify the components responsible for optical variability. Thus, the scientific objectives of this projects which are to: (**1**) separate in situ the bulk iops into size ranges (Fig. 1b) with the hypothesis that distinct classes of particulate material can be separated by size and that these classes will be acted upon by different physical, chemical and biological processes; (**2**) separate the size fractionated *a* coefficient into phytoplankton and non-phytoplankton components (Fig. 1c-d) each of which will certainly be prone to different physical, chemical and biological processes; (**3**) quantify the relative contributions of the size-fractionated components in the major water masses that occupy the shallow continental shelf waters (Fig. 1e); (**4**) quantify the optical variability of these size-fractionated component iops within and between these major water masses; (**5**) relate the conservative and non-conservative optical variations to specific physical and bio/chemical processes; (**6**) quantify the time scales of vertical mixing using non-conservative optical variability.

APPROACH

An integrated optical profiling system, consisting of three WETLabs ac9s (one donated by Dr. Heidi Sosik), a WETLabs safire (data collected for Dr. Paula Coble), an FSI micro CTD, a and a WETLabs SuperMODAPS, was deployed with the ship's CTD/rosette package to obtain optical and physical measurements concurrent with discrete water samples. In situ fractionation of the iops was obtained by placing filter cartridges on the intake ports of the ac9s. Multiple profiles per cast enabled more than three size fractions to be obtained. Filter pore sizes were 0.2, 3, 5, and 10µm. Dr. Anne Petrenko (USC) was subcontracted to collect the in water iop data for the spring CMO cruise (1997).

All water samples were analyzed immediately upon collection except for nutrients samples (nitrate, phosphate, silicate) which were immediately frozen and stored for later analysis. Pigment concentrations were determined fluorometrically and by HPLC. Particle composition,

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concentration, and size distribution were determined with a Galai CIS100 Particle Analyzer (Roesler and Hansing, submitted). Absorption coefficients for colored dissolved organic material (CDOM) were measured spectrophotometrically on 0.7μm filtrate. Particulate absorption coefficients were determined using the quantitative filter technique with correction for pathlength amplification (Roesler, submitted). The particulate absorption coefficients were separated into contributions by phytoplanktonic pigments and tripton using the methanol extraction method (Kishino et al., 1985). Additional separation of the organic and inorganic particulate absorption is modeled according to Roesler et al. (in prep). Jennifer Simeon (UConn) was the head technician responsible for all sample analyses with help of Mary Kay Talbot (subcontracted for CMO96 from UWash.) and Stacey McLeroy-Ethridge and Kam Wing Tang (UConn graduate students participating in CMO97).

Size-fractionated particulate absorption coefficients measured in situ were partitioned into phytoplankton and tripton components (Roesler et al., 1989) with modifications for the ac9 (Roesler and Zaneveld, 1993). Size-fractionated scattering and size-fractionated component-specific absorption coefficients were determined for the major water masses occurring at the station (as identified by TS relationships). Total optical variability is separated into conservative (i.e. between water masses) and non-conservative (i.e. within water masses) components. Conservative optical variability will be used to investigate the physical processes associated with advection, mixing and passage of internal waves and solitons. Non-conservative optical variability (photo-oxidation of surface CDOM, phytoplankton photoacclimation) will be used to investigate the time scales of mixing processes.

WORK COMPLETED

Two three-week cruises were successfully undertaken in July-August 1996 and April-May 1997 to the continental shelf south of Nantucket (40°30' N, 70°30' W). All water sample analyses have been completed. Over one hundred optical casts were performed per cruise yielding over three profiles per day of at least three size classes of iops. All optical profiles, collected with the MODAPS, have been extracted and merged with the CTD data into separate iop and spectral fluorescence data files (the latter of which was given to Paula Coble). Temperature and scattering corrections (Pegau and Zaneveld, 1993; Roesler and Zaneveld, 1993) of the iop data files are nearly complete. Initial quantification of the size-fractionated component-specific iops for individual water masses has been performed on a subset of the data from the summer cruise (Roesler et al., 1997).

RESULTS

The water column encountered during the summer cruise was characterized by highly stratified conditions and clearly defined populations of optically active components within distinct size classes (Fig. 1). Against this stable condition was the occasional appearance of advected continental slope water characterized by large tripton particles (symbols in Fig. 1), the passage of solitons, and intense mixing due to Hurricane Eduoard. Optical variability was dominated by conservative processes associated with advection, mixing and internal waves.

During the spring cruise, the conditions were characterized by a highly dynamic water column with intervals in stratification and destratification lasting on the order of days (Fig. 2a). The trend of increasing absorption associated with phytoplankton was interrupted by the periods of destratification, vertical mixing, and dilution of the phytoplankton. Large phytoplankton were associated with destratification, smaller cells with stratification, CDOM was highest below the pycnocline (Fig. 2b-d). The composition of the phytoplankton was not constant with a general inverse relationship between the diatoms and dinoflagellates (Fig. 3). Optical variability during this period was dominated by non-conservative processes associated with local increases in phytoplankton biomass and conservative processes associated with mixing.

IMPACT/APPLICATION

In order to understand the variability in bulk inherent optical properties, it is necessary to deconvolve the signal into the components that comprise the bulk material. The approach presented in this project is to quantify the optical variability associated functional groups of different size classes, thereby increasing the ability to interpret bulk optical variability with greater confidence. More importantly, the component optical variability can be attributed to conservative and non-conservative processes providing additional means to study physical and biological processes in the ocean.

TRANSITIONS

The in situ size fractionation, developed and tested in 1993 by Scott Pegau, Ron Zaneveld and myself, is now being used by most ac9 owners. Further fractionation into functional groups has been used in NRL-funded LOE and COPE experiments in collaboration with Dr. A. Weidemann.

RELATED PROJECTS

1. Jennifer Simeon, my technician, and I have quantified the optical variability along the upwelling region of the Equatorial Pacific (Simeon et al., in prep.); ship time on the Zonal Flux Experiment provided by Jim Murray (UW).
2. I am investigating the relationship between iops and irradiance reflectance in collaboration with Norman McCormick (UW) and his student, Bob Leathers.
3. Davnet Conway, my student, is investigating the utility of single excitation/emission fluorescence signatures to identify and trace the source of DOM in Long Island Sound and Chesapeake Bay(shiptime provided by NRL).
4. Jeremy Werdell, my student, is testing a model to extract benthic reflectance from surface reflectance measurements to identify the dominant benthic habitats in Long Island Sound.

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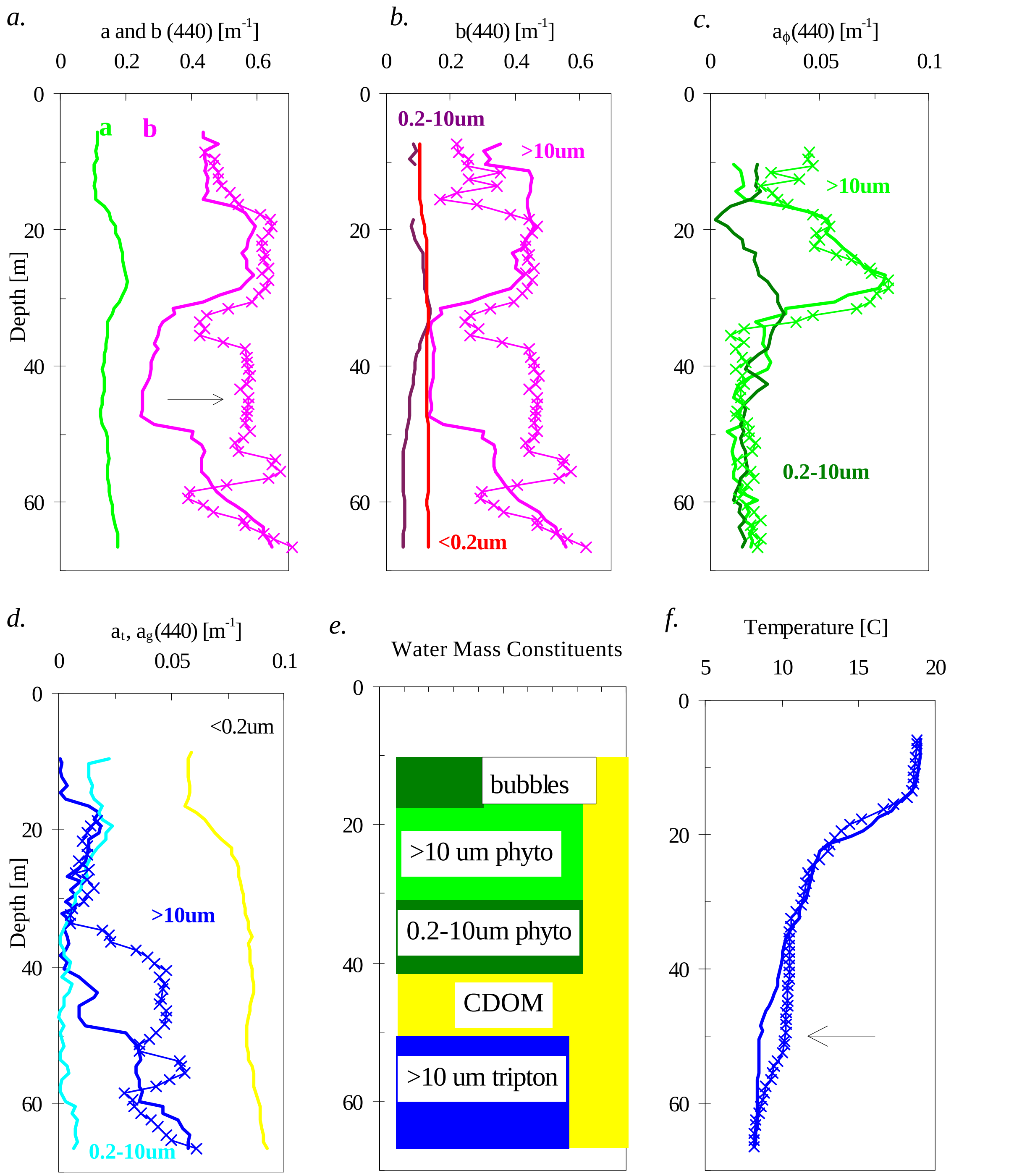

Figure 1. Iops at 440 nm measured in situ with ac9s at 1200h (lines) and 1500h (symbols) on 25 August 1996. Size fractionation performed in situ by placing filter cartridges on the intake ports of the instruments. Scattering coefficients calculated from c-a; size ranges calculated by difference; phytoplankton and tripton components estimated from size-fractionated measured particulate absorption (total - <0.2μm) using the model of Roesler et al. (1989). *a*. Absorption (green) and scattering (magenta) coefficients; *b*. scattering coefficients for three size ranges; *c*. phytoplankton absorption coefficients for two size ranges; *d*. absorption coefficients for gelbstoff and two size ranges of tripton; (*f*) distribution of dominant components in the water column (1200h) as determined by the size fractionated component iop measurements; temperature profiles for 1200h and 1500h (arrow indicates the intrusion of slope water).

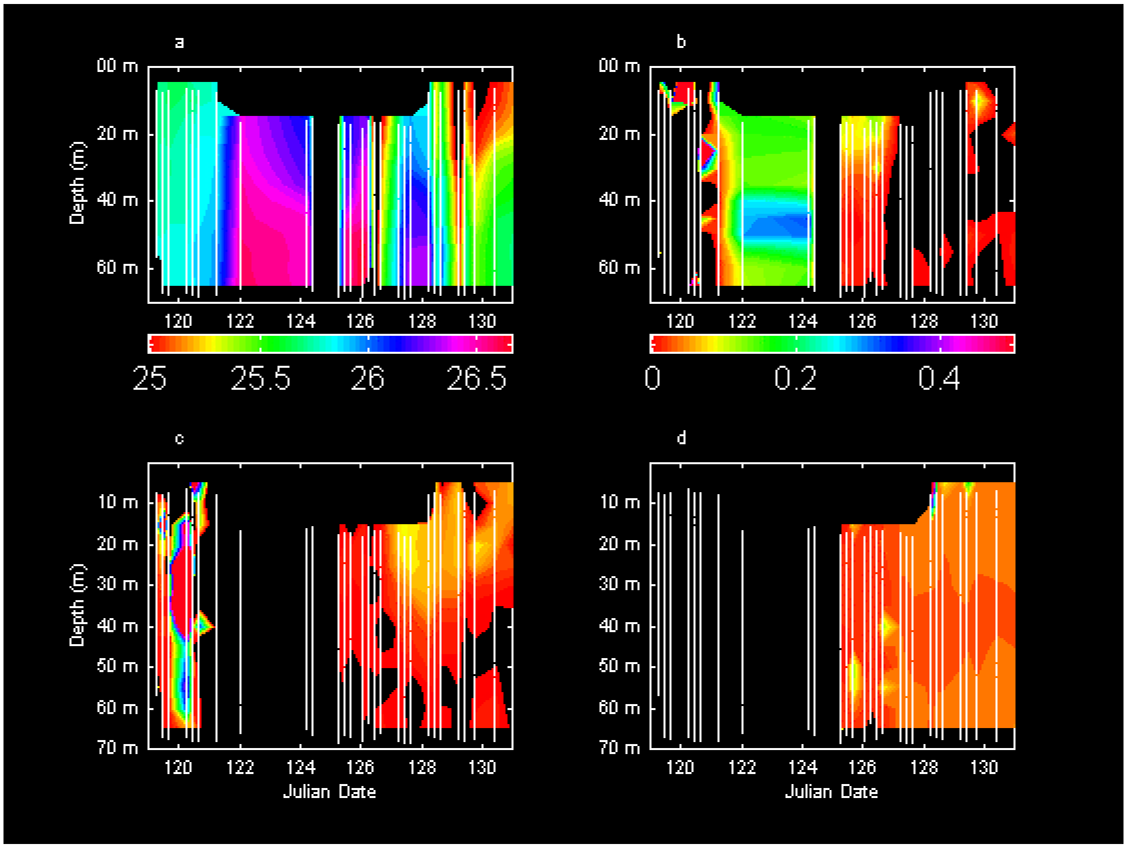

Figure 2. Physical and absorption characteristics of the water column during the spring cruise April May 1997. *a*. Density (σ_T) values indicated by color bar. Absorption at 440 nm for the size classes: *b*. >5 µm, *c*. 0.2-5 µm, and *d*. <0.2 µm (CDOM). Vertical lines indicate profile location. Magnitude [m^{-1}] indicated by right hand color bar, applies to b-d. Only data from JD 125 to 131 is presented for CDOM; in all other figures no data were collected on JD 125, otherwise the absence of values indicates essentially zero absorption by that component.

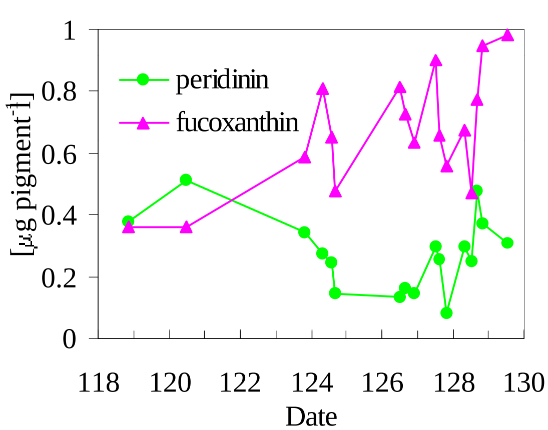

Figure 3. Surface pigment concentrations determined by HPLC over an twelve-day period in spring 1997. The general trend suggests that diatoms are temporally incoherent with dinoflagellates, as indicated by fucoxanthin and peridinen, respectively.